Residential Ventilation Effectiveness in the Pacific Northwest

Field Study of Mechanical Ventilation Effectiveness in Tightly Constructed Houses

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Study Credits

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Research Supported by the Northwest Energy Efficiency Alliance

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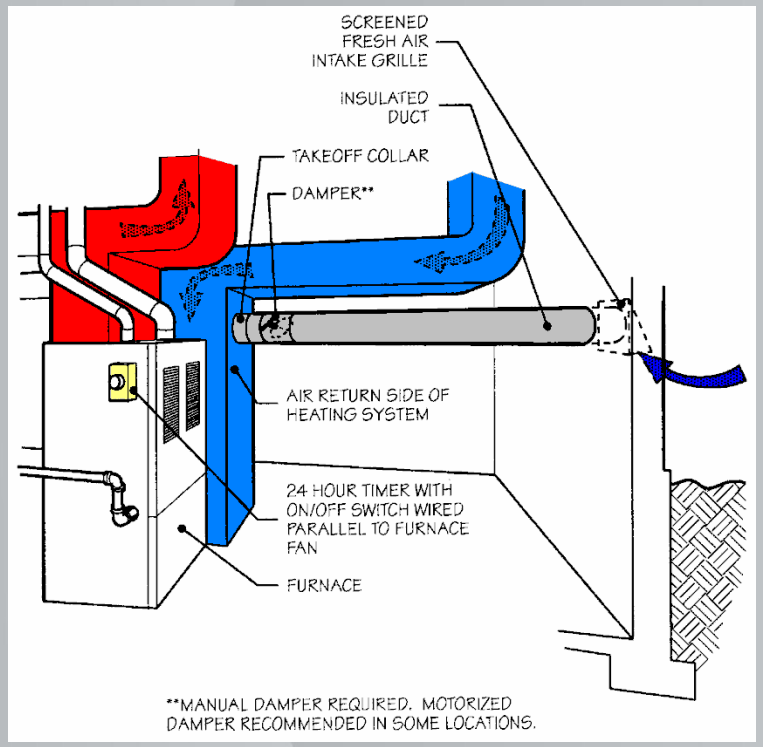
History

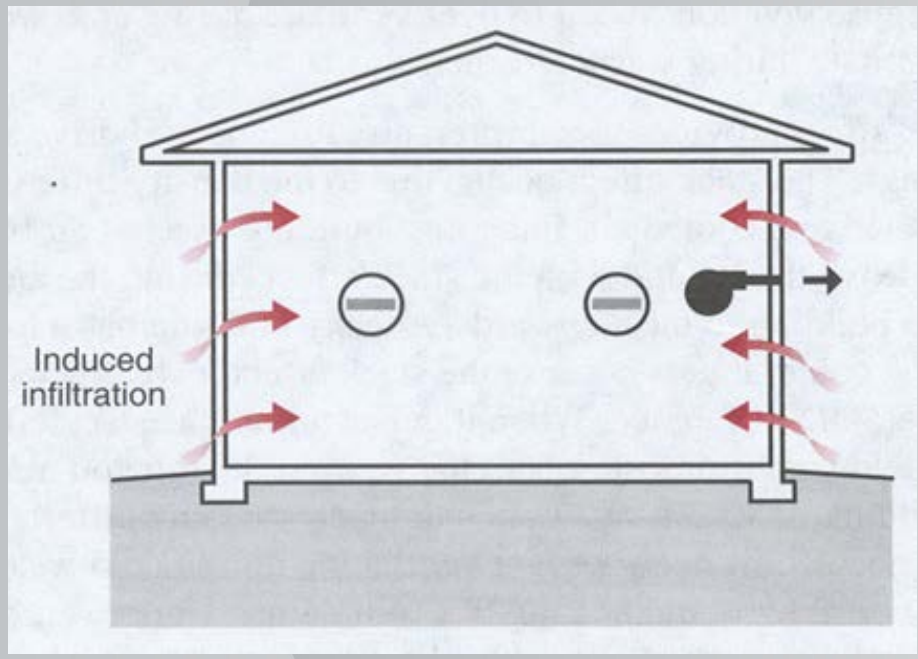
- Mechanical whole house ventilation required in residential construction in Washington State since July 1, 1991. VIAQ Code
- First statewide requirement in U.S.
- Based on ASHRAE 62.2 1989
  - 15 CFM/occupant or .35 ACH
- In 22 years about 800K homes
- 1991 WA State Energy Code assumed tight houses < .1 ACH “Seal all penetrations”

Ventilation System Types

Integrated with Central Forced Air



Exhaust Only



What Really Happened

- Houses did not get as tight as assumed.
  - Tested average of WA Code homes since 1991
  - Result- .37 ACH (7.4 ACH50)
- Systems often did not work properly, were turned off or disabled by occupants.
- If operated often over ventilated especially during colder seasons.
- Not a lot of complaints or problems.

What's Happening Now

- WA Code required blower door testing to about .285 ACH since 2009 (tested av. .31)
- 2012 WA Code .25 ACH started 7/1/13
- 2012 IECC requires tested 3 ACH50 (.15 ACH)

It may really matter if ventilation systems actually work and are operated!

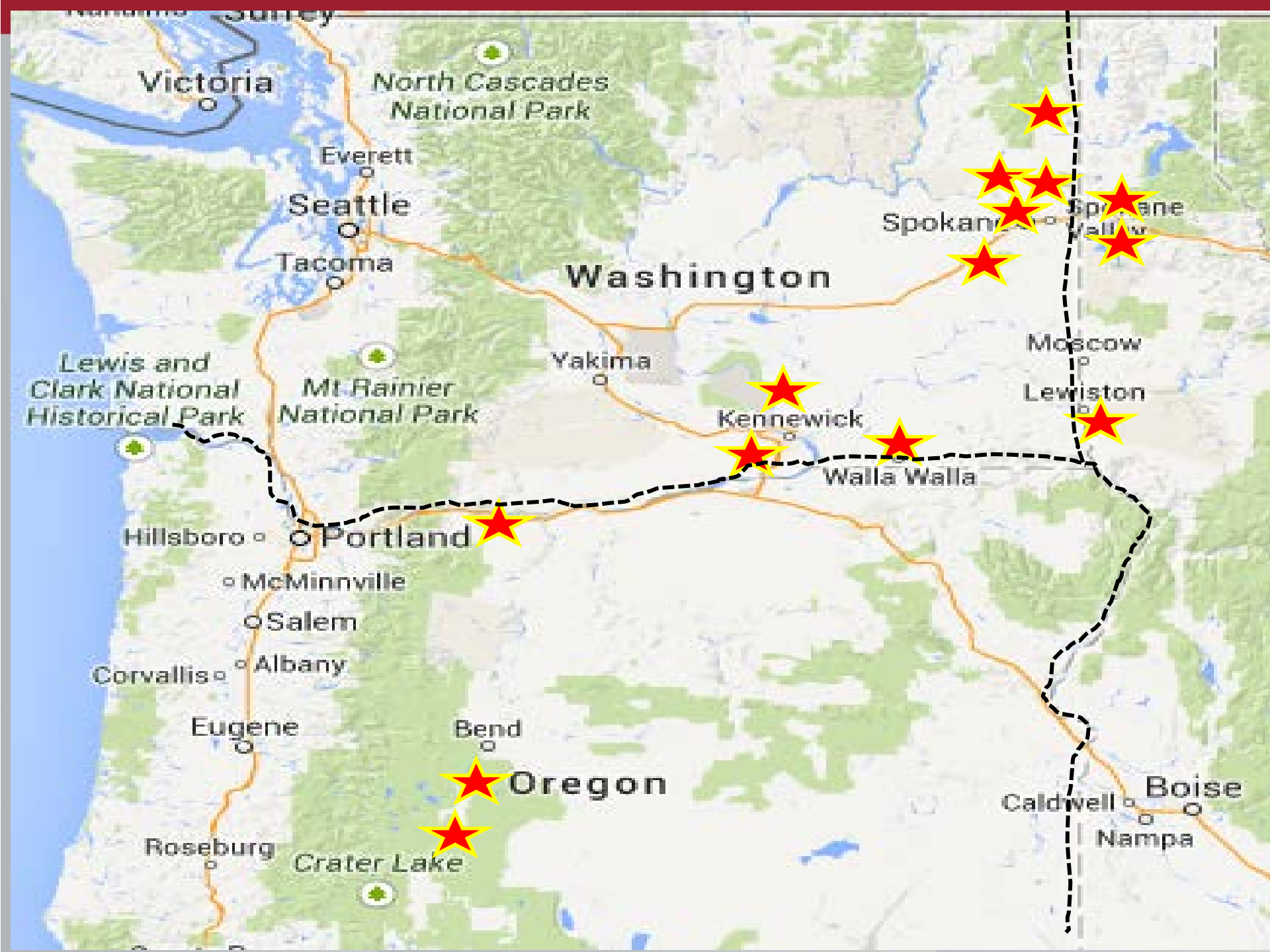
What is Happening Now

- Most really tight houses (2 ACH50 or less) have HRVs. Conventional wisdom is they work but they are expensive.
- Super tight, high performance homes are moving away from CFA so integrated ventilation is less common option. They work with low up front cost but high operating costs (big fan).
- Single point exhaust only systems are relatively low cost, economical to operate but how well they actually work?

Ventilation Effectiveness Field Study

What questions did we want to try and answer?

1. How well do different types of ventilation systems work in really tight houses (<3ACH50) in terms of compliance with ASHRAE 62.2 2010?
2. What is the efficacy of different systems in terms of watts/CFM as operated?
3. How does door closure (especially in bedrooms) affect the performance of different types of systems?
4. Do trickle vents improve the performance of exhaust only systems?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North Cascades National Park
Everett
Seattle
Tacoma
Washington
Spokane
Moscow
Lewiston
Yakima
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Lewis and Clark National Historical Park
Mt Rainier National Park
Hillsboro
Portland
McMinnville
Salem
Albany
Corvallis
Eugene
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Oregon
Roseburg
Crater Lake
Caldwell
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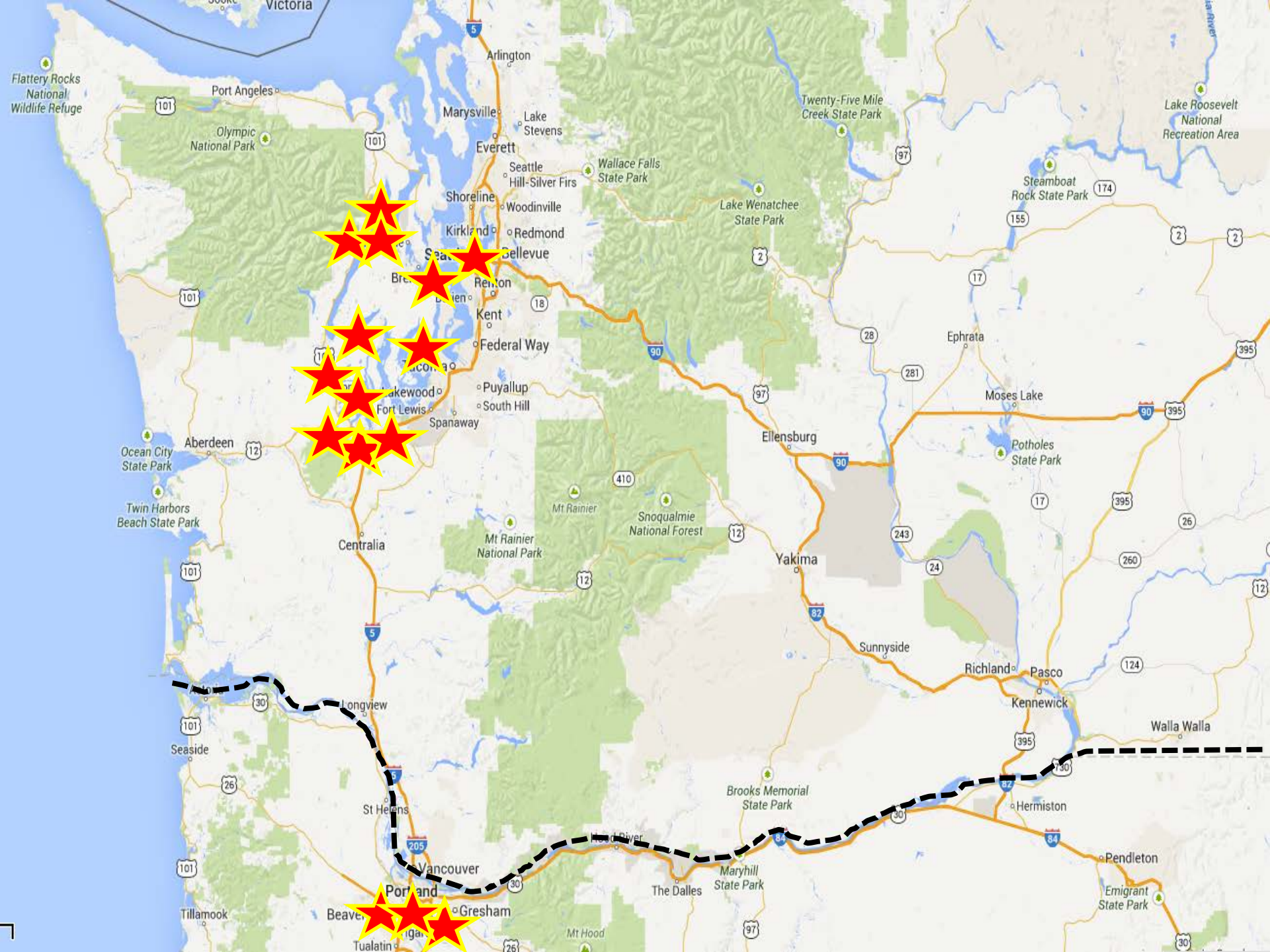
Nampa


Victoria
Flattery Rocks National Wildlife Refuge
Port Angeles
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Marysville
Lake Stevens
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Seattle
Hill-Silver Firs
Wallace Falls State Park
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Woodinville
Kirkland
Redmond
Bellevue
Renton
Kent
Federal Way
Lakewood
Puyallup
South Hill
Fort Lewis
Spanaway
Aberdeen
Ocean City State Park
Twin Harbors Beach State Park
Centralia
Mt Rainier
Mt Rainier National Park
Snoqualmie National Forest
Twenty-Five Mile Creek State Park
Lake Wenatchee State Park
Steamboat Rock State Park
Lake Roosevelt National Recreation Area
Ephrata
Moses Lake
Potholes State Park
Ellensburg
Yakima
Sunnyside
Richland
Pasco
Kennewick
Walla Walla
Brooks Memorial State Park
Hermiston
Pendleton
Emigrant State Park
Maryhill State Park
The Dalles
Longview
Seaside
St Helens
Vancouver
Portland
Gresham
Tillamook
Mt Hood

Matrix of ACH_{50} and Vent Systems

System Type	House < 1 ACH50	House < 2 ACH50	House < 3 ACH50
Exhaust Only	1	4	2
Exhaust Only with Trickle Vents	1	3	4
Integrated with CFA*			2
HRV	6	3	1
HRV Integrated with CFA*			2

1. Sample selected from ~ 900 homes built 2006 or newer (final sample 29 sites).
2. Screened out occupants with respiratory problems.
3. Single family detached or multi-family with no more than 1 common wall.
4. Roughly ½ sites marine climate zone 4 and ½ cold climate zone 5.
5. Occupants agreed not to open windows during test cycles.

**Central Forced Air*

House Characterization

- General: size; volume; bedrooms, occupancy; stories; type heating/cooling; type ventilation; ventilation operation; foundation type; garage.
- Inventory of all exhaust appliances: type; location; flow (cfm); power draw of ventilation equipment.
- House tightness; duct leakage to exterior.
- Pressure mapping: incremental depressurization induced by exhaust air flows and CFA operation.
- Pressure induced across closed bedroom doors when whole house ventilation operated.
- Tracer gas decay on 90% of sites; ventilation off/on; bdrm doors open/closed.

Monitoring

- Monitored CO2, temp. & %RH in master bdrm, secondary bdrm and core living area (15 min data).
- Monitored door closure of master and secondary bdrms.
- Monitored run times of whole house ventilation systems.


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Vent Fan
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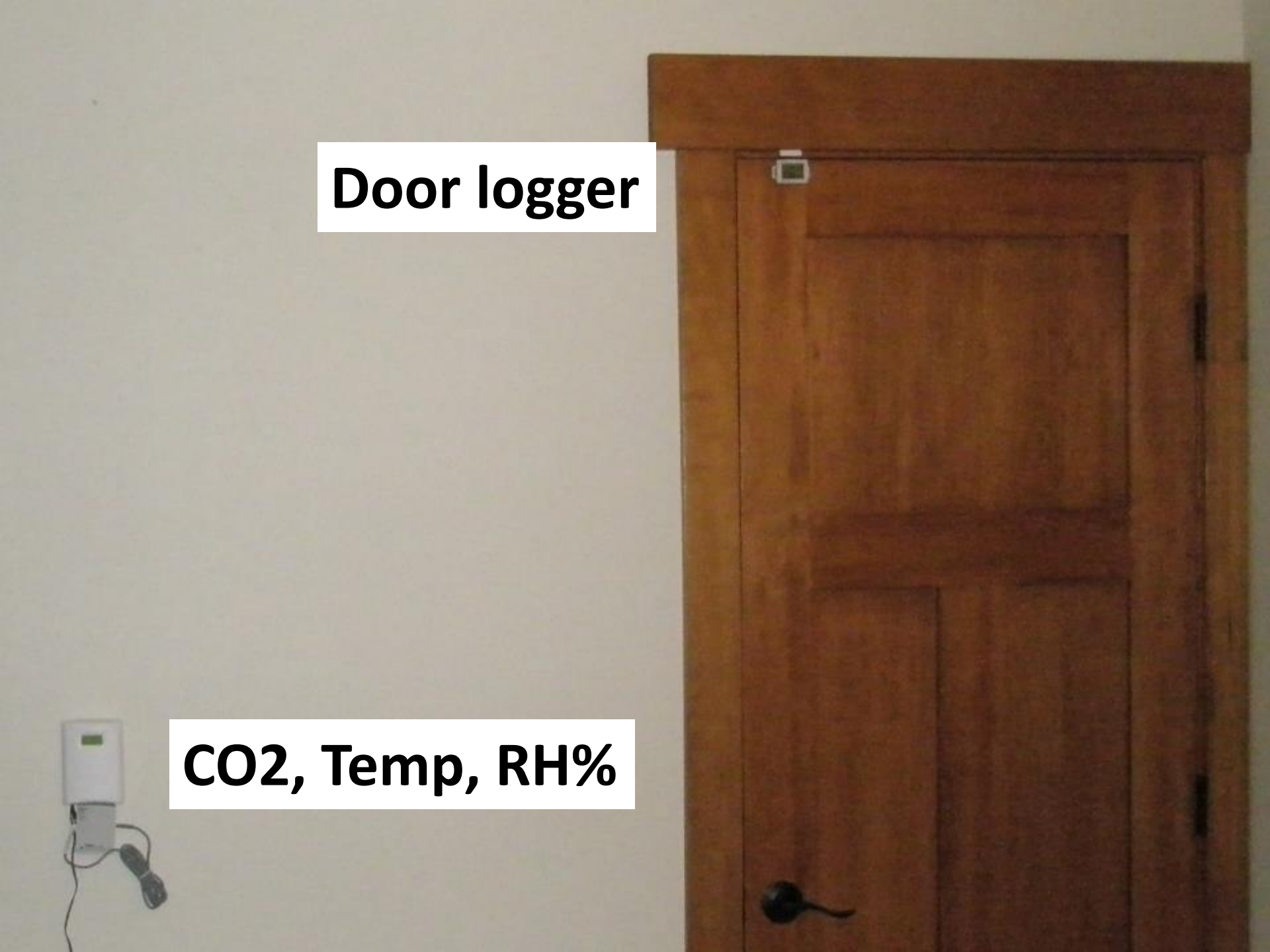
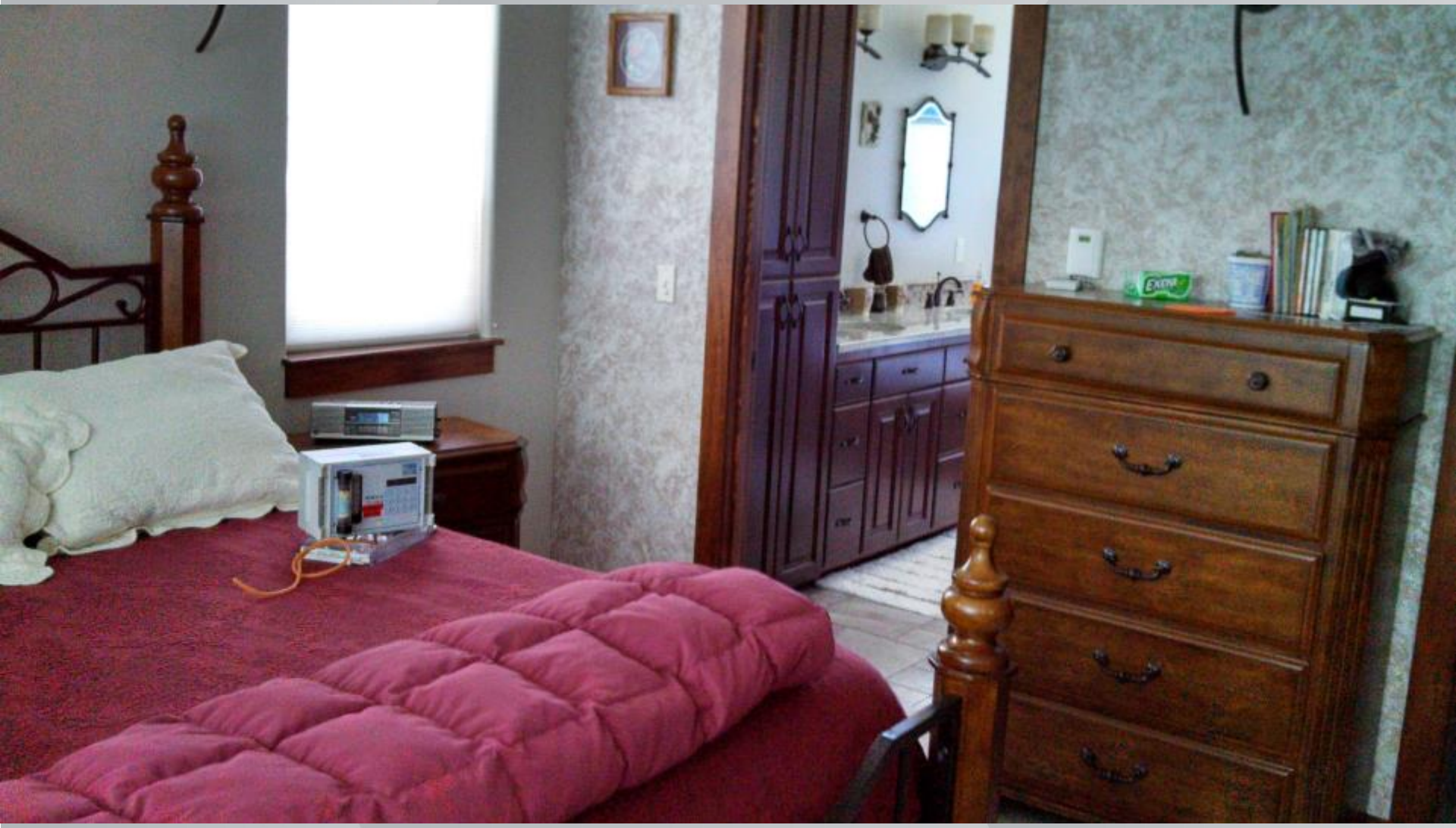

Door logger
CO2, Temp, RH%



Test Cycles

7 day test cycle periods (included weekends)

Occupants provided with detailed test calendar and Journal* WSU weekly reminders via phone/email

Test configurations:

- **Whole house ventilation on/off**
- **Bedroom doors open/closed**
- **Trickle vents open/closed (as applicable)**

Heating and Spring season The test cycles at each house performed in cold winter conditions and repeated during mild spring

*Occupants logged system and house & exhaust appliance operation, activities, changes in occupancy

Data and Analysis

What is Effective Ventilation?

- Really complex
- Dynamic interaction of:
  - Structural characteristics of the house
  - Different mechanical systems & operation
  - Outside environment
  - Occupants & occupancy patterns
  - Pollutant sources & strengths

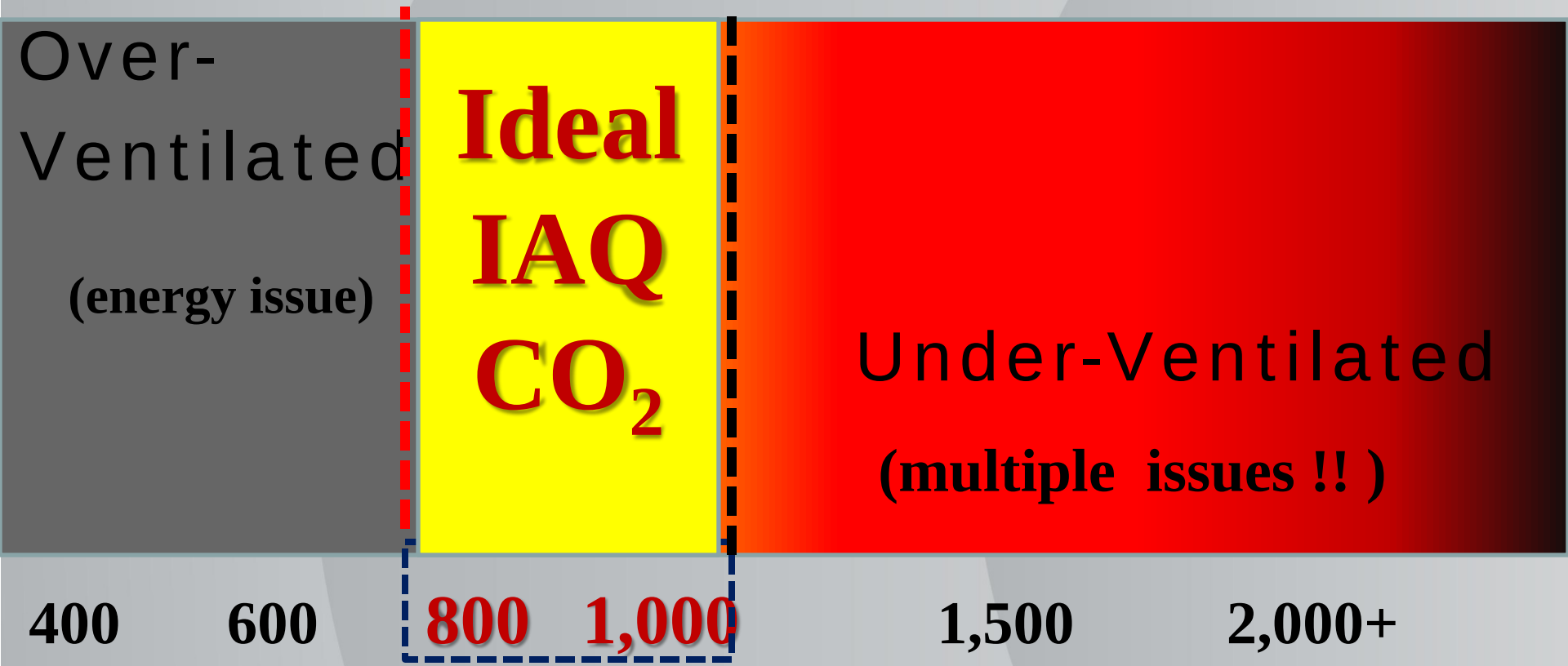
Our Analysis

- Assumed that ventilating to ASHRAE 62.2 2010 was the goal.
- Used C02 levels generated by occupants as a tracer gas to estimate CFM/occupant at steady state.
- Focused on occupied bedrooms at night

Carbon Dioxide vs. Ventilation Rate

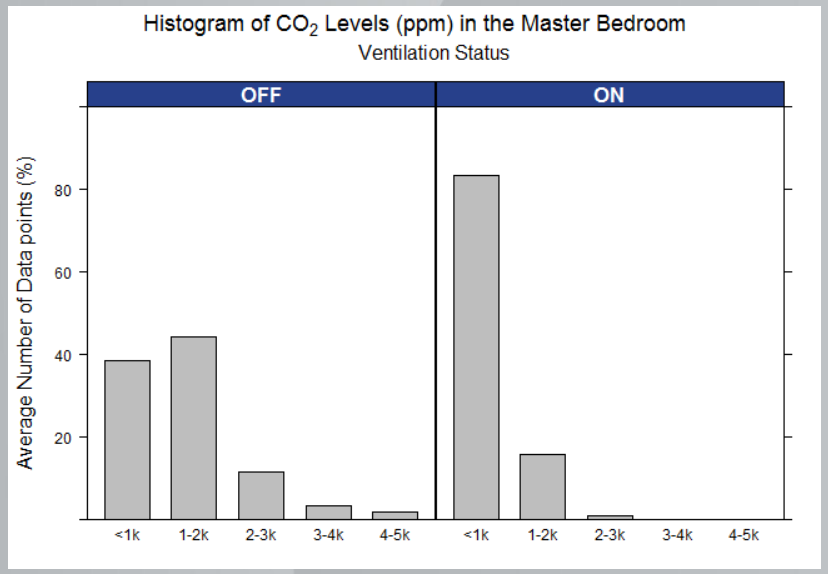
Carbon Dioxide (ppm)	Outside Air	
2,400	----- 5 cfm/p	Unacceptable
1,400	----- 10 cfm/p	Poor
1,000	----- 15 cfm/p	ASHRAE Standard 62
800	----- 20 cfm/p	
600	----- 25 cfm/p	
400 (and above)		Outdoor

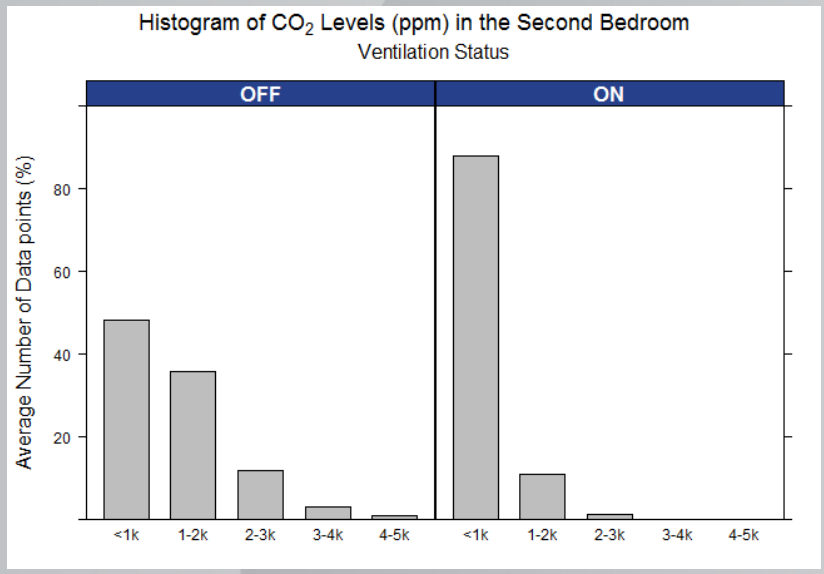
CO_2 Estimate of Ventilation

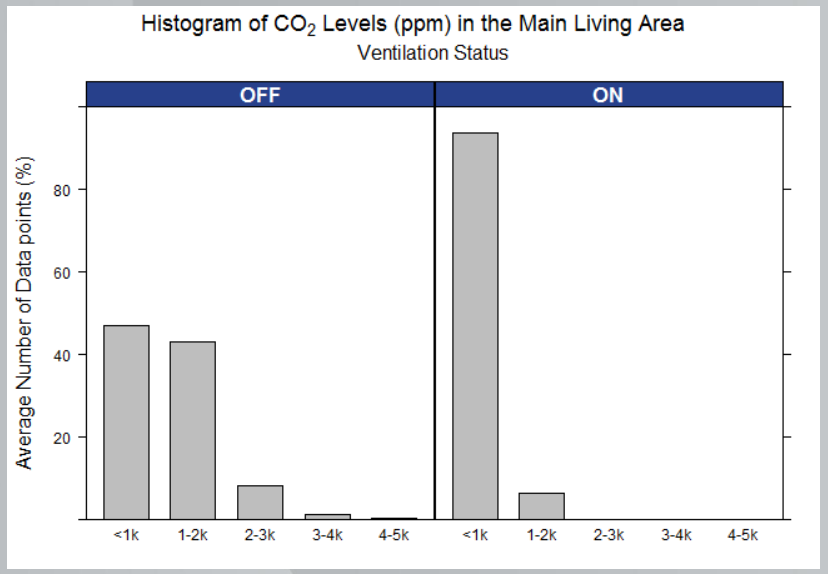


LONG TERM CO_2 TESTING

CO2 Level Distribution with Ventilation On or Off

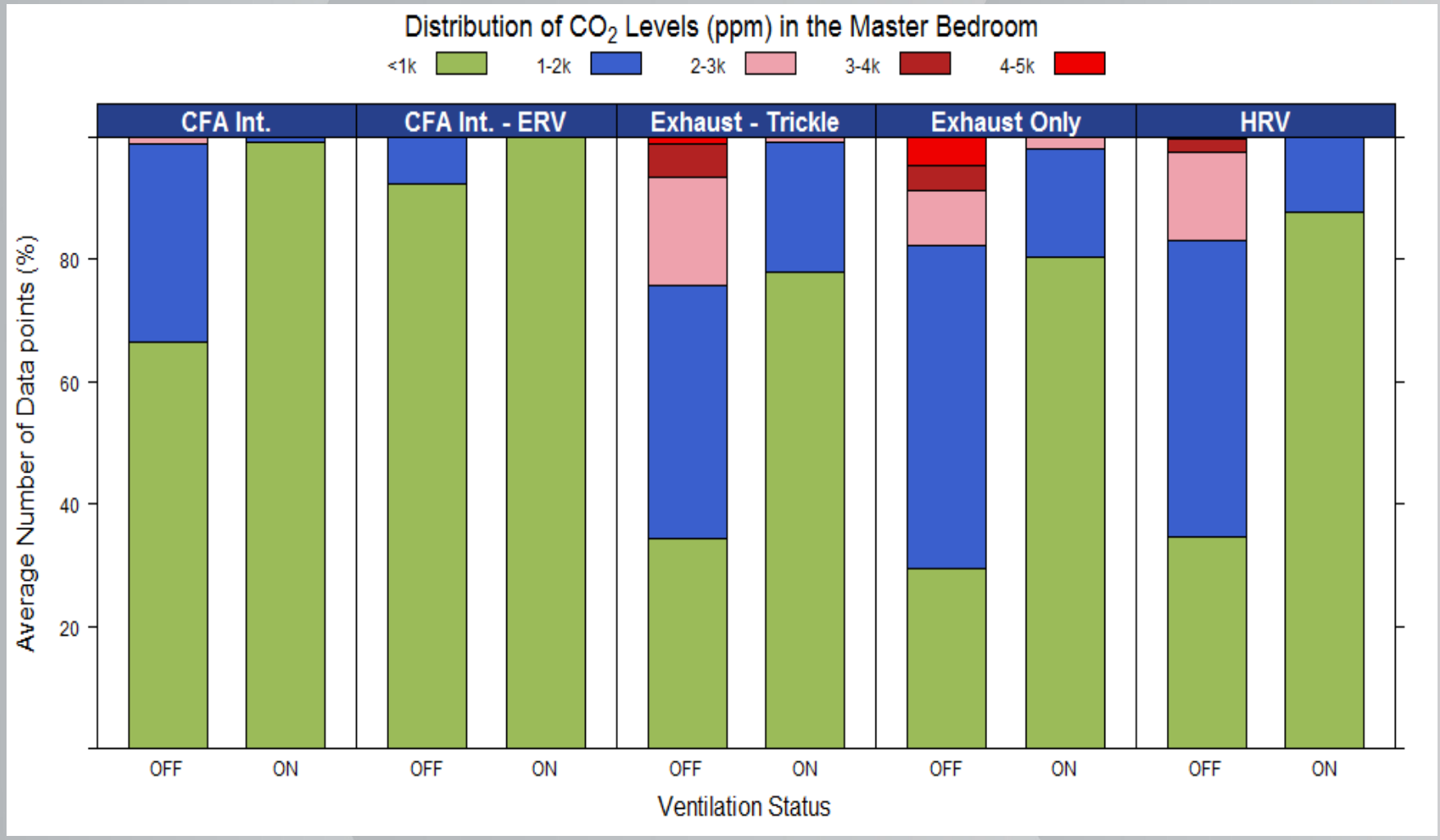






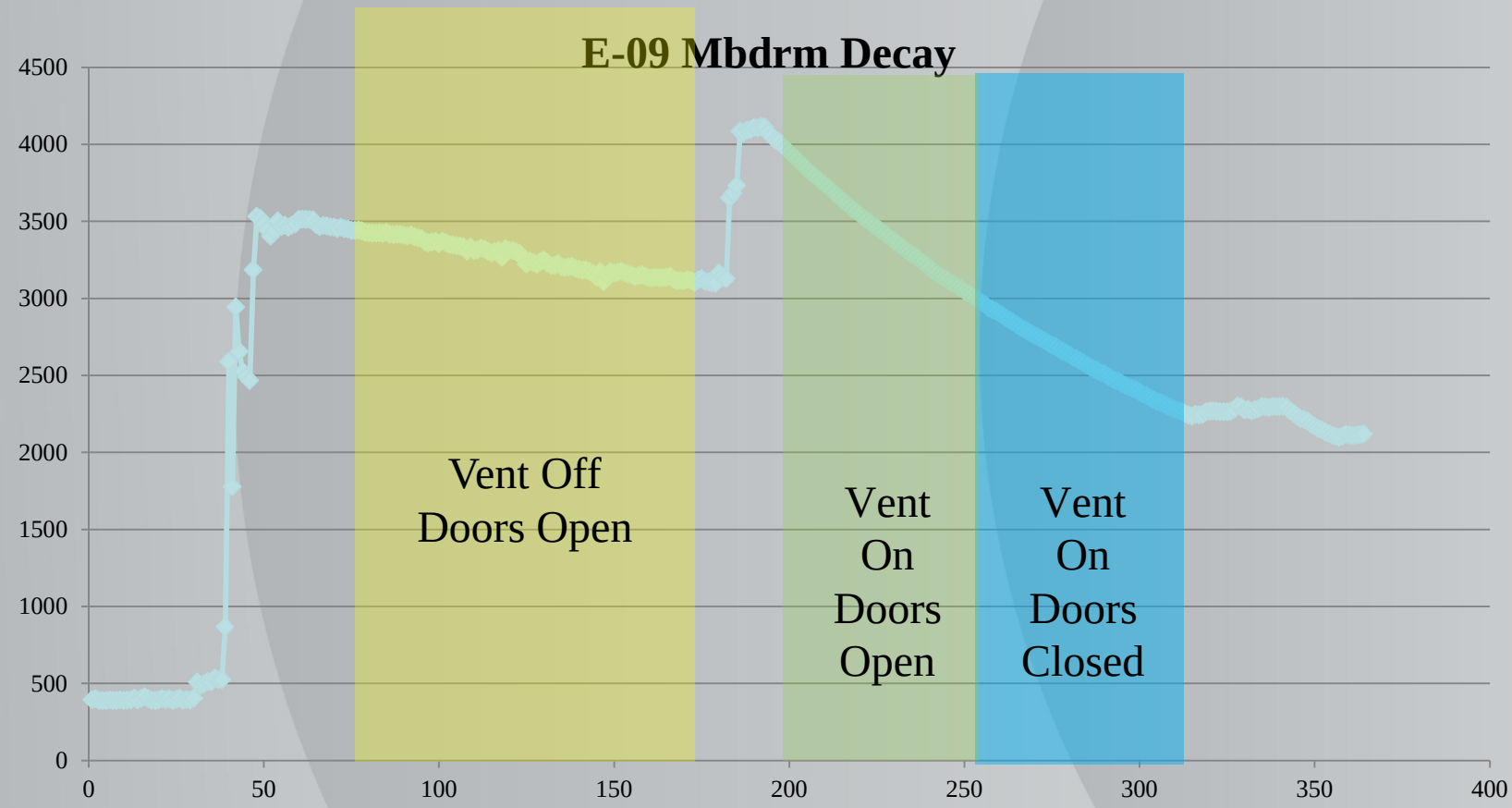
Ventilation Works

CO_2 Level Distribution by Ventilation Type with Ventilation On or Off



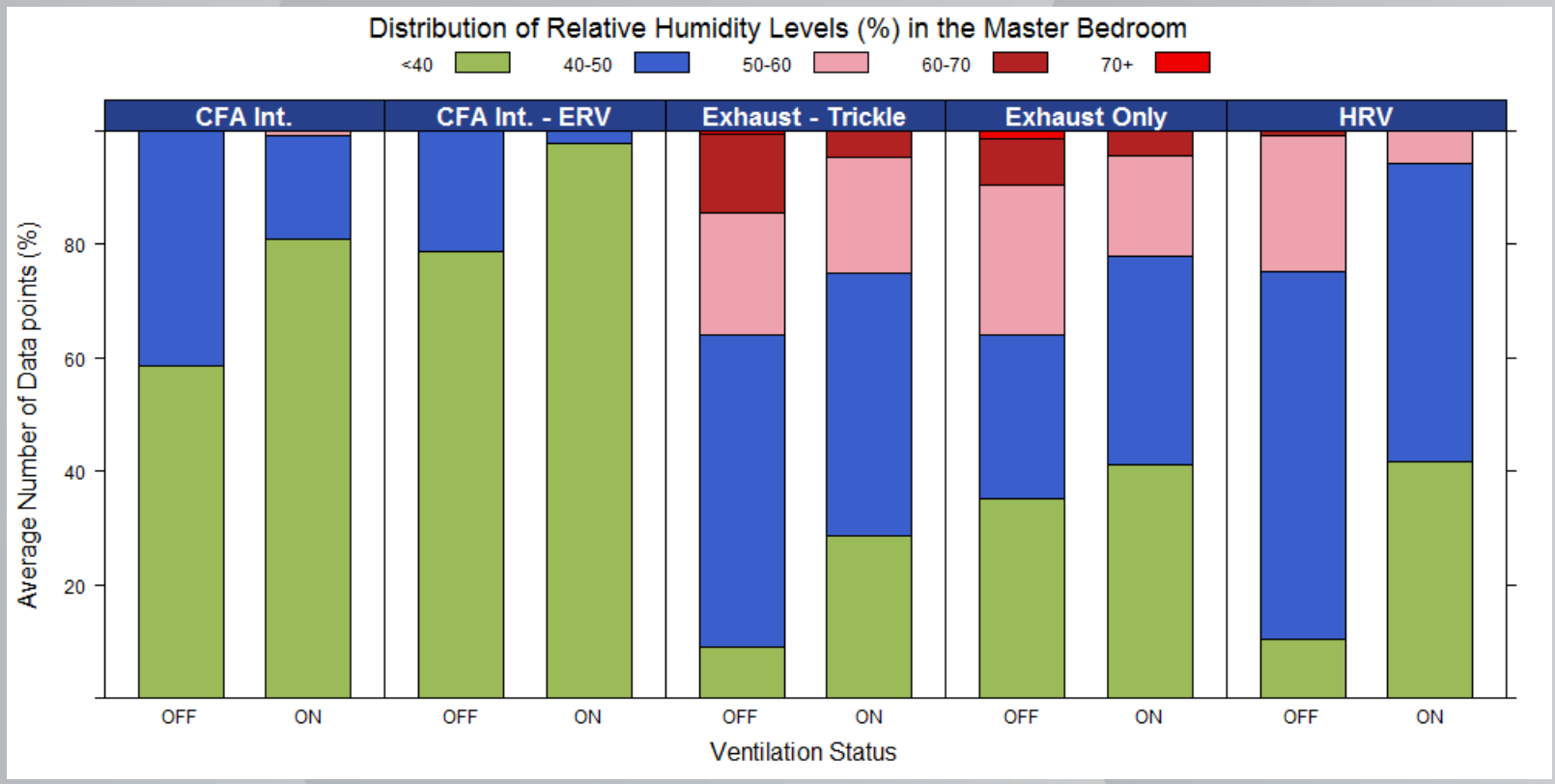
TRACER DECAY TESTING

CO_2 Tracer Decay Integrated CFA System



RELATIVE HUMIDITY

Relative Humidity Levels by Room, Ventilation System, and Ventilation Operation



Some Conclusions

- Without ventilation these houses have very low ACH rates (<0.1) potentially allowing significant build up of pollutant concentrations.
- Operation of the ventilation system increased the ACH rate by a factor of 4 on average.
- Door closure has a larger impact on ACH rates in zones without direct distribution or active mixing.

Other Areas of Study

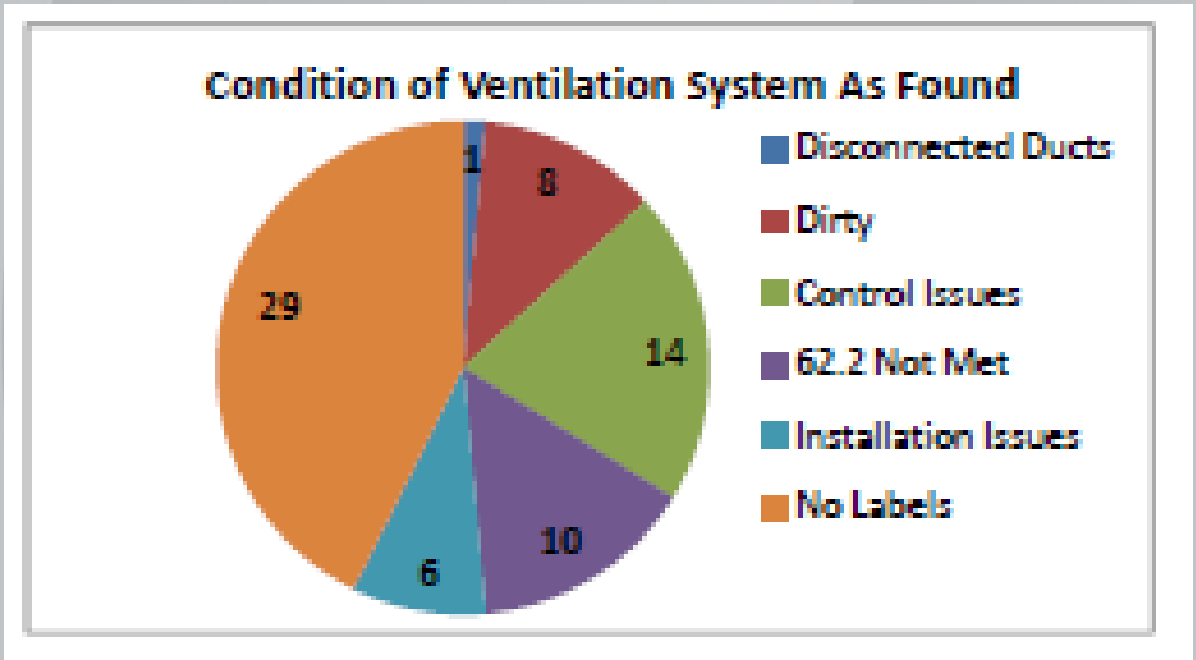
- Monitored door closure data
- Fan energy used by ventilation systems
- As found system condition
- Ventilation performance as found
- Occupant knowledge of the ventilation system and its operation and maintenance
- Performance of trickle vents

Fan Energy by System Type

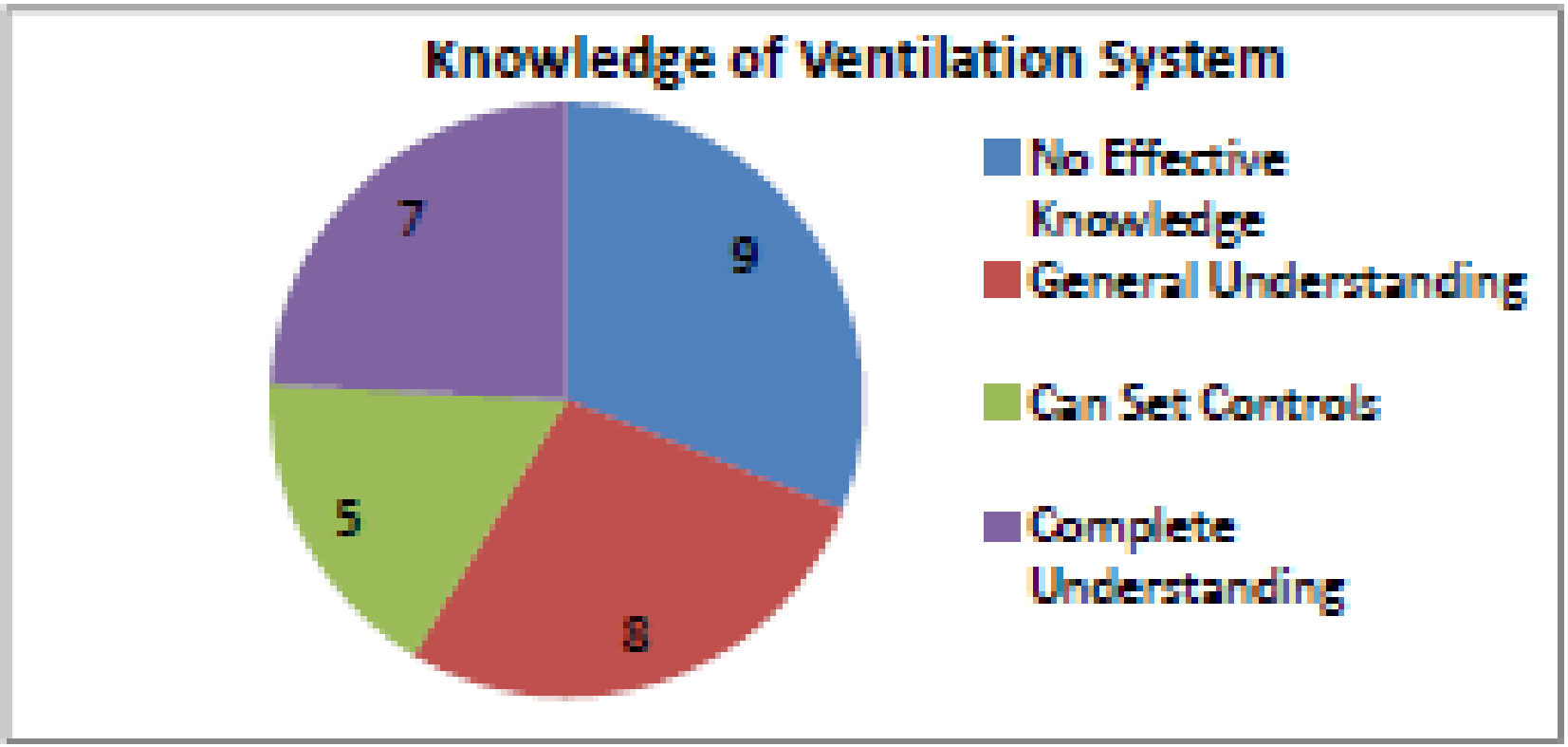
Table 14. Estimated electricity use by ventilation system type

System Type	Count	Average (kWh)	High (kWh)	Low (kWh)	Standard Deviation (kWh)
EO	15	162	547	34	139
HRV/ERV	11	499	765	193	196
Integrated with CFA	3	1,072	1,564	515	431
All	29	384	1,564	34	351

As Found Conditions



Occupant Knowledge of System Operation & Maintenance



Full Report

HTTPS://CONDUITNW.ORG/PAGES/FILE.ASPX?RID=2585

VIDEO FOR CONSUMERS ON WHOLE HOUSE VENTILATION

HTTP://WWW.ENERGY.WSU.EDU/BUILDINGEFFICIENCY/ENERGYCODE.ASPX#PRESENTATIONS

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